

# **Parametric Modeling for Fluid Systems**

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# Parametric Modeling for Fluid Systems

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Fluid Systems involves different projects that require parametric modeling, which is a model that maintains consistent relationships between elements as is manipulated. One of these projects is the Neo Liquid Propellant Testbed, which is part of Rocket U. As part of Rocket U (Rocket University), engineers at NASA's Kennedy Space Center in Florida have the opportunity to develop critical flight skills as they design, build and launch high-powered rockets. To build the Neo testbed, hardware from the Space Shuttle Program was repurposed. Modeling for Neo, included: fittings, valves, frames and tubing, between others. These models help in the review process, to make sure regulations are being followed. Another fluid systems project that required modeling is Plant Habitat's TCUI test project. Plant Habitat is a plan to develop a large growth chamber to learn the effects of long-duration microgravity exposure to plants in space. Work for this project included the design and modeling of a duct vent for flow test. Parametric Modeling for these projects was done using Creo Parametric 2.0.

## Nomenclature

ECS	= Environmental Control Subsystem
HCU	= Humidity Control Unit
HEPA	= High Efficiency Particulate Air
ISS	= International Space Station
KSC	= Kennedy Space Center
NASA	= National Aeronautics and Space Administration
ORU	= Orbital Replaceable Unit
PH	= Plant Habitat
PTC	= Parametric Technology Corporation
Rocket U	= Rocket University
RU	= Rocket University
TCUI	= Temperature Control Unit
WRADS	= Water Recovery and Distribution System

## I. Introduction

The creation of product models continues to evolve as 2D drawings are converted to 3D. Parametric 3D models ensure that all engineering constraints are met. Parametric modeling is a type of modeling which is aware of the characteristics of components and the interactions between them, maintaining consistent relationships between elements as the model is manipulated. Parametric modeling is useful for: planning, estimating cost, on the presentation of plan for approval; structural, pressure, proper fitting analysis, between others.

KSC's Fluids & Propulsion Division involves different projects that require parametric modeling. One of these projects is the Neo Liquid Propellant Testbed, which is part of Rocket U. As part of Rocket University, engineers at NASA's Kennedy Space Center in Florida have the opportunity to develop critical flight skills as they design, build and launch high-powered rockets.

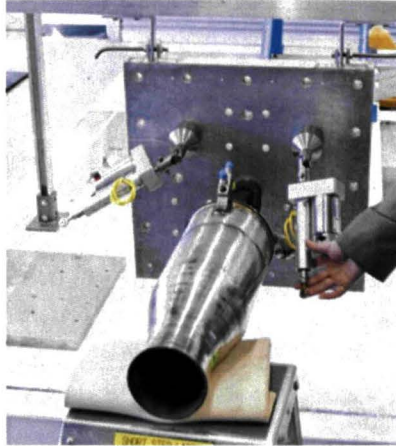
After the Space Shuttle Program shut down in 2011, hundreds of engineers at Kennedy Space Center started redirecting their focus from the Shuttle processing towards flight systems engineering. To advance this new effort, managers at the Kennedy Space Center developed a small low-cost training program: Rocket University. This

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program promotes: collaboration between centers, technical and systems engineering development, and team skill building. RU classes and labs provide valuable experiences similar to those gained during the long-term, large-scale flight projects, but on smaller, short-term, low-cost scale. RU curriculum's was built around the idea that good systems engineers can handle both technical leadership and systems management. RU students take classes and put their knowledge to test on a lab flight project or experiment. One of these projects being, NEO which is a testbed to test the Injector 71 rocket engine as shown on Figure 1.



**Figure 1. Injector 71 Engine on test fixture  
NASA/Frankie Martin**

Another fluid systems project that required modeling is Plant Habitat's Temperature Control Unit (TCUI) test project. Plant Habitat is a plan to develop a large growth chamber to learn the effects of long-duration microgravity exposure to plants in space. NASA's Microgravity Research Program along with the scientific community and the commercial industry, aims to increase understanding of the effects of microgravity on biological, chemical and physical systems. Gravity influences everything on Earth, from the way life has developed to the way materials interact. However, on board a spacecraft orbiting the Earth, the effects of gravity are hardly felt. In this "microgravity environment," scientists have a unique opportunity to study the states of matter, and the forces and processes that affect them, in a way that would not be possible on Earth. Cooperation with academia and private industry in space-based, biotechnological research continuously help in the production of technical innovations for the improvement of health care on Earth.

Plant Habitat is required to provide a large, enclosed, environmentally controlled chamber designed to safely support commercial and fundamental plant research onboard the International Space Station (ISS). PH will combine proven microgravity plant growth technologies with newly developed fault tolerance and recovery technology to enhance general efficiency and reliability. PH's design is based on an open architecture concept to allow critical subsystems to be removed and replaced onboard the ISS.

## **II. Software**

Parametric Modeling for both of these projects was done using PTC Creo Parametric 2.0. In order to upload all the files created during the modeling to the database, called KDDMS, a workspace in their respective servers for each project was created. Before creating or adding a part to the main assembly it is always convenient to create a sub-assembly and place it there, this gains importance with the increase of the number of parts in a model. Second, when creating a part or sub-assembly a proper name must be picked. Creo restricts naming options by not allowing the use of spaces or symbols, other than underscore, and the repeating of names. To avoid repeating the name of a part or assembly that is already on the KDDMS server that is currently in use, it is recommended to add the initials of the current project as prefix of the name. When placing a part, is necessary to define at least three restraints (x, y, z directions), unless the part is equally in the radial direction, where only two, an axis and another, would suffice. The hierarchy of the references is important when placing a part or defining an extrude. One should be dependent on another in a chain-like way, if there is codependents, "circular references" will happen, in which case the model

would not properly regenerate after a modification. Some parts needed for modeling are sometimes located in the KSC library; these parts can be placed in the assembly but can't be modified, and frequently come from a generic part/family in which case the needed size is selected. On fortunate times a model of a commercially found part is available, if not modeling is necessary; in most of these cases a drawing with specs is available. If no model or specs are found for a part, its dimensions are measured with a caliper or appropriate measuring tool and then modeled. For fluid systems projects, as habitual, Creo's Piping application was used to design the general tubing. After a part is finished, the parameters (material, weight, part number, classifications, etc.), must be added. To contain some of these parameters a WTpart must be created for the part.

### **III. Rocket U**

#### **A. Background**

A group of engineers at Kennedy Space Center are developing engine design and system test requirements experience for the Project Neo Liquid Propellant Testbed of the Engineering Directorate's Rocket University. The Neo testbed is currently for the Injector 71 rocket engine, which was used previously on an Armadillo Aerospace lunar lander prototype. The Injector 71 engine uses super-cooled propellants, liquid oxygen and liquid methane. Liquid oxygen and liquid methane would come from their respective dewars, pass through different tubing and valves to reach the engine and react, creating thrust.

#### **B. Modeling done for this project**

The parametric model for this project was already started; hence the work for this project, during this internship, consisted in updating this model; adding new parts and subassemblies, as well as editing the existing parts and assemblies. Since the Neo testbed was constructed from repurposed Space Shuttle Program hardware, the steps that the project would ordinarily take differed. Instead of finishing the whole parametric modeling, then request the parts needed and build it; the parts needed were searched for, integrated in the physical assembly and then integrated in the 3D model along the way.

First, flow meters were modeled per the flow meter specifications. Two were modeled, one necessary for each line; since the engine runs on oxygen and methane, two lines (of different diameter) pass along the assembly. A list of the fittings, nuts, and reducers that would be used for a segment of each line was made, looked up in the KSC library and incorporated in their respective subassemblies. Subsequently, custom tubes (flared) to be used with the fittings were modeled following drawing specs. The model for the ball valve that passes through each of these lines was updated in shape and color and custom fittings were added to further resemble its physical characteristics. The bracket which is used to attach the ball valve to the bar and subsequently the skid, the engine spark plug, shut-off valve and temperature bulb were modeled following the physical measurements made with a caliper, since there were no drawing found for these. One of the reducers was a custom part, due to the fact that it is not part of the library, physical measurements and the merging of other two library parts was needed. The two thermocouples, one for oxygen and one for methane, that sit close to the engine, were modeled following spec drawings from the company. The two subassemblies where the thermocouples sit were redone with other library fittings. Based on the sketch of a current Unistrut part, more parts of different lengths were made and used in the assembly to place the ball valve. Using the Piping Application in Creo, flexible tubes were created to connect fittings ends near the engine.

#### **C. Future**

Further, on the respective modeling for this project, a frame placed on top on the skid, on the opposite end from where the engine is placed, will be updated with the tubing and instruments placed on it, including the control box and its respective cabinet cooler and tubing. Phase 1 of the project is to fire an engine with about 3,000 pounds of thrust. For Phase 2, after the goals from phase one are accomplished, the next goal, would be to eventually integrate the engine to a flight vehicle. The project has also considered using the testbed to test other engines.

### **IV. Plant Habitat**

#### **A. Background**

As part of ensuring PH works properly and as efficiently as possible, it is going to be subjected to the TCUI test. This test would simulate how the PH controls growth chamber temperature and humidity by mixing air through metal fins over porous ceramic materials so that water may pass in either direction. Subsequently, thermoelectric



modules are used to condition the water in the porous metallic materials to attain air humidification or dehumidification and to condition the air to reach required temperature set point. Henceforth, the condensed water is recovered by the Water Recovery and Distribution System (WRADS) and the air passes through a 300 micron screen and High Efficiency Particulate Air (HEPA) filter to help guard the components of the Environmental Control Subsystem (ECS). The temperature and humidity will be controlled and observed via the instrumentation, regulated by LabView. The system, consist of a duct vent attached to a duct assembly with a coldplate and, Orbital Replaceable Unit (ORU) and Humidity Control Unit (HCU) house. In sum, this test would provide data of power consumption for the fan and thermoelectric coolers versus the amount of heat rejected; information of the conditions, which would make for a more capable and longer-lasting PH system.

### B. Modeling done for this project

Most of the modeling for this project was focused on the design for a duct vent. The design for the duct vent prototype followed the overall dimensions of the old model, as shown in Figures 2 and 3, and the following requirements: be able to fit filter end, and able to hold an anemometer.

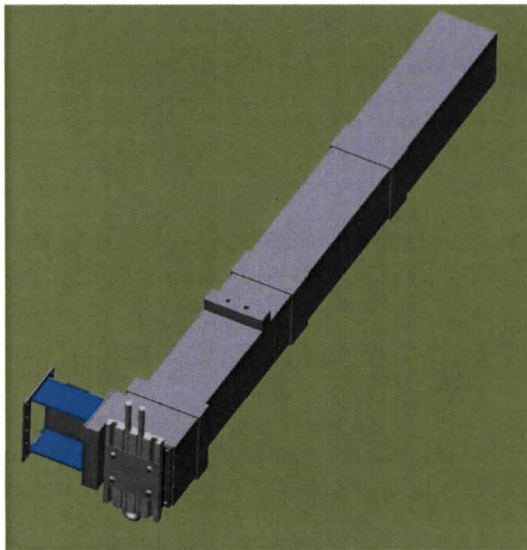


Figure 2. Original model duct

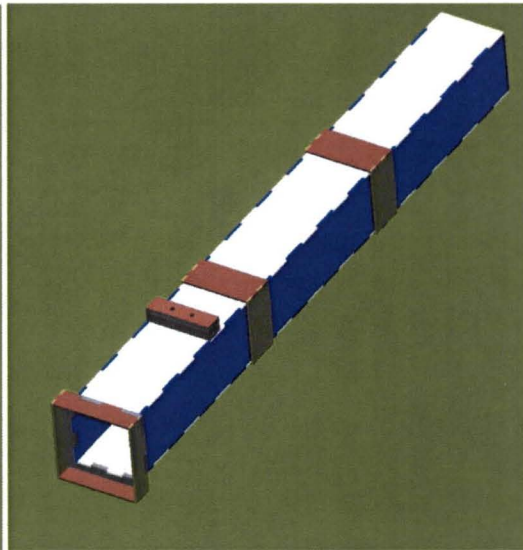


Figure 3. Duct with multiple pieces and pattern

The duct was also designed to be able to be disassembled in three parts. It was made of polycarbonate. The parts were design to be fit like a puzzle and glued. The parts follow a rectangle zigzag pattern with different dimensions depending on its length and the thickness of the fittings parts, as shown is Figure 4.

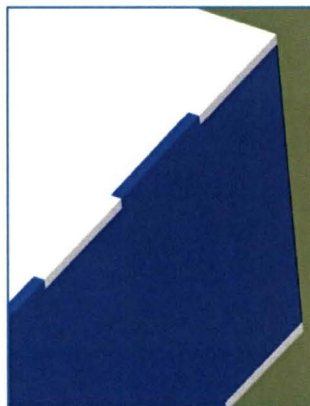


Figure 4. Close-up pattern

For design simplicity many of the parts were repeated in the model; they just needed to be flipped to fit together. Out of 29 parts total, there were only 9 parts designed. The polycarbonate parts were manufactured from a water jet and then glued with polycarbonate cement.

Further work for this project includes the revision of the fan model to make sure it follows specs. The proper parameters were added to a WTpart, created in order to add it like a library part.

### C. Future

Plant Habitat is scheduled to launch to space to be integrated to the ISS in December of 2015.

## V. Conclusion

Parametric modeling is very important in the process of: planning, estimating cost, on the presentation of plan to review boards, making sure the parts fit and are placed together properly, and preceding possible future problems. Neo is a critical project for engineers at KSC to gain technical and systems engineering experience. Hopefully, the HP will serve as an effective tool to discover more about the effects of micro-gravity on plants, which would be essential in the future to help support life in space.

## Acknowledgments

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